CLAIMS

1. A method of reducing metal oxide material to metal comprising the steps of:-

(i) circulating a first molten carrier material in a closed solid-state reduction loop serially through a charge reduction zone and a combined melt desulphurisation and heating zone;

(ii) circulating a second molten carrier material in a closed melt refining loop serially through a melting zone and a desulphurisation/decarburisation zone

(iii) introducing a mixed composite charge comprising a metal oxide and a carbonaceous reductant onto the surface of the carrier material in the reduction zone of the solid-state reduction loop,

(iv) reducing said metal oxide to solid metal by the carbonaceous reductant in the reduction zone, the metal oxide and carbonaceous reductant being introduced in step (iii) in proportions such that the carbon from the carbonaceous reductant is converted to carbon monoxide, hydrogen gas also being produced;

(v) separating a metallised raft containing the solid metal from said molten carrier material by projecting said metallised raft into the refining loop upstream of the heating zone of the solid-state reduction loop so that the surface of the first molten carrier material which is circulated to the heating zone is substantially free of solid material;

(vi) mixing the carbon monoxide and hydrogen formed in step (iv) and partially combusting the mixture in the melt refining loop in order to satisfy the thermal requirements for melting the metallised raft and for the chemical reactions taking place in the desulphurisation/decarburisation zone and providing the gaseous oxygen mixture containing no free oxygen in order to effect decarburisation;

(vii) optionally carrying out further partial combustion of the carbon monoxide and hydrogen to melt solid scrap or direct reduced material;

(viii) after steps (vi) and (vii), mixing the carbon monoxide and hydrogen with oxygen and completely combusting the mixture well above the melt in the heating zone of the solid-state reduction loop so that although direct flame impingement is facilitated, no unreacted oxygen comes into contact with the melt in providing the full thermal requirements for reduction of the oxide charge materials in the solid state by transfer to the first molten carrier material which is recirculated to the solid-state reduction zone;

(ix) submitting the carbon monoxide and hydrogen to hot gas cleanup for removal of sulphur and solid particulates prior to step (vi), (vii) or (viii);

(x) melting the metallised raft in the melting zone of the refining loop and refining the molten metal in the desulphurisation/decarburisation zone, and

(xi) removing the metal so refined from the refining loop.

2. The method as claimed in claim 1, wherein the composite charge additionally comprises a flux.

3. The method as claimed in claim 2, wherein said flux is selected from lime, limestone and dolomite.

4. The method as claimed in any preceding claim, wherein said metal oxide is selected from one or more of iron, chromium, nickel and manganese oxides.

5. The method as claimed in any preceding claim, wherein the composite charge added in step (iii) forms a layer having a thickness of from 5 cm to 20 cm, preferably 5 cm to 10 cm, on the first carrier material.

6. The method as claimed in any preceding claim, wherein the composite charge is at least partially compacted prior to step (iii).

7. The method as claimed in any preceding claim, wherein the ratio of carrier material to metal to be produced is from 100:1 to 500:1, preferably 200:1 to 400:1.

8. The method as claimed in any preceding claim, wherein the charge reduction zone of the solid-state reduction loop is constituted by a first hearth and the desulphurisation/heating zone is constituted by a second hearth, a flowpath being provided between a downstream end of the first hearth and an upstream end of the second hearth and between a downstream end of the second hearth and an upstream end of the first hearth.

9. The method as claimed in any preceding claim, wherein the melting zone of the refining loop is constituted by a third hearth and the desulphurisation/decarburisation zone is constituted by a fourth hearth, a flowpath being provided between a downstream end of the third hearth and an upstream end of the third hearth and between a downstream end of the fourth hearth and an upstream end of the third hearth.

10. The method as claimed in claim 9, wherein said flowpaths are provided by gas lift pumps or siphons.

11. The method as claimed in any preceding claim, wherein the velocity of the carbon monoxide produced in step (iv) increases toward the downstream end of the charge reduction zone.

12. The method as claimed in any preceding claim, wherein hot gas clean up is effected between steps (iv) and (viii).

13. The method as claimed in any preceding claim wherein any slag produced in step (iv) is removed from the carrier material before the latter is passed into the desulphurisation/heating zone.

14. The method as claimed in any preceding claim, wherein step (v) is achieved by maintaining a shallow depth of the first molten carrier material in a crossover between the melt circulation loop and the refining loop, so that the metallised raft floats on the first molten carrier material and is transferred to the refining loop by drag forces exerted by the first molten carrier material.

15. The method as claimed in any preceding claim, wherein the metal removed from the refining loop in step (viii) is passed to an additional refining loop for further refining..

17. A metal refining apparatus comprising:-

(i) a solid-state reduction loop comprising first and second hearths, a continuous flowpath existing between a downstream end of the first hearth and an upstream end of

the second hearth and a downstream end of the second hearth and an upstream end of the first hearth,

(ii) a refining loop comprising third and fourth hearths, a continuous flowpath existing between a downstream end of the third hearth and an upstream end of the fourth hearth and a downstream end of the third hearth and an upstream end of the fourth hearth,

(iii) means for introducing a composite charge into the upstream end of the first hearth,

(iv) means for transferring, in use a metallised raft floating on a molten carrier material from the downstream end of the first hearth to the upstream end of the third hearth,

(v) ducting for transporting gases generated in the first hearth to the third hearth for partial combustion,

(vi) ducting for transporting the partially combusted gases in the third hearth to the fourth hearth for further combustion,

(vii) ducting for transporting the partially combusted gases in the fourth hearth to the second hearth for complete combustion with oxygen, and

(viii) a hot gas clean up unit in the gas flowpath between the first and third hearths or between the third and fourth hearths.